able that the contagion does not enter the tree through ordinary wounds caused by men or animals.

(4) The fact that the disease can be transmitted artificially through the root system makes it probable that trees may also become infected naturally in this way.

(5) Experimental proof of the identity of the peach rosette and the plum rosette is still incomplete.

(6) None of the yeasts or bacteria found in the cultures made from diseased tissues produced the disease when inserted into the cambium, and it is probable that the disease is not due to such organisms.

(7) In both natural cases and those induced by budding, the disease progresses gradually from the point of infection until all parts of the tree are involved. Even when a tree shows symptoms in all parts at once, as is very often the case in early spring, we may assume that the cause of infection entered through the roots during the previous summer or autumn and was gradually diffused through the whole tree in the months immediately preceding the vernal symptoms, as was certainly the case in the seven root-grafted trees.

(8) The shortest period of incubation was about two months (Bull. No. 1, p. 49) and the longest period about ten months, but one-half of this longest period was the winter season, during which the trees were dormant.

(9) The disease is probably conveyed through the protoplasm and the failure to isolate any pathogenic yeast or bacterium suggests the possibility that the cause is some amœboid organism living in the protoplasm and so much resembling it as to be difficult of detection. Such an hypothesis would explain all the facts. That the disease is due to any chemical ferment or other readily soluble substance seems out of the question, for the upward and side movements of the water imbibed by the roots would certainly carry it to all parts of the growing tree within a few hours or a few days at longest. Moreover, such a substance possesses no indefinite power of multiplication. Whereas, in this disease a very small fragment will induce symptoms in a whole tree, any part of which will then induce the disease in another tree.

REMEDIES FOR THE ALMOND DISEASE CAUSED BY CERCOSPORA CIRCUMSCISSA, SACC.

By Newton B. Pierce.

[Plates xviii-xx.]

Since the publication of the author's former paper on the almond disease so prevalent in southern California,* spraying experiments have been conducted in Orange County, which have clearly demon-

*Journal of Mycology, Vol. vii, No. 2, pp. 66-77.

strated that the disease may be controlled at moderate expense and in a thoroughly satisfactory manner. The suggestions of B. T. Galloway in regard to the treatment of this disease have proven of value.* From experiments now completed, and from additional facts gathered in relation to the habits of the parasite, there may now be outlined a very satisfactory plan of treatment.

The trees selected for the experiments were on the place of J. S. Baldwin, about 1 mile east of the village of Orange. They were badly infested by *Cercospora* in 1891, and had lost nearly all of their foliage by the latter part of July. By the 1st of August, 1892, the untreated trees were in worse condition than at the same date the preceding year, and only a few shoots had developed during the spring. There were 34 trees included in the experiment, and they formed a single row about 800 feet long, running from west to east through an orchard composed of various fruits. They were twelve years old and were grown on a soil of gray loam mixed with more or less gravel. The care given them has been but moderate. Many of the tops were well formed and of good size, while others were smaller and stunted in growth, owing to poorer soil. The branches, with the exception of a few terminal ones, were alive, but up to August 1 but little growth had been made and most of the wood of last season's growth was ready to die back. These trees leafed out fully in the spring of 1892 and received the first treatment in April.

Prior to the beginning of this season's work the almond foliage was supposed to be annually infected in the early spring by spores which came mainly from the fallen leaves of the previous year's growth. It has since been learned that infection of the spring foliage is mainly accomplished by means of spores produced on the terminal twigs of the tree, *i. e.*, on the last season's shoots. There is some evidence also that *Cercospora* may become nearly or quite biennial in its habits when living on almond branches. It even appears probable that in some cases it lives in the tissues of the twig through the mild winters of southern California and produces in the following spring a sufficient number of spores to infect the new foliage. Some observations seem to point to even a perennial life for the fungus, in rare cases. Be this as it may, it is evident from the way the tree first shows the disease in the spring that the new terminal leaves are infected directly from the last year's wood. Branches on all parts of the tree show disease first on the leaves at the end. This is as true of the uppermost limbs as of those next the ground, which would not be the case if the infecting spores came from either fallen foliage or the soil.

The spring infection is usually general over the outer branches, but in many cases it is more complete and the work of the fungus shows earlier on the north than on the south side of the tree. This may arise in part from the greater humidity on the north, due to shade, and the conse-

Ibid., pp. 77–78.

quent conditions favorable to germination, and from the fact that the prevailing winds are from the southwest and naturally blow more spores to the north side of the tree.* It has already been noted that five-sixths of the infested points on the branches occur on the lower two-thirds. This is in harmony with the above facts, and arises from a like reason—the greater humidity on the shaded side.

After the parasite has become well developed on the outer leaves infected from the terminal twigs and abundant spore clusters are formed, the foliage toward the center of the tree becomes infected. The parasite spreads from the terminal leaves to those at the base of the limbs, and the fall of the diseased foliage follows essentially in the same order, although as the basal leaves are the older their fall is in consequence somewhat hastened.

From the preceding facts it will be seen that sprays applied after the outer leaves are infected, but before the fungus has matured fruit, may still prevent its spread to the main mass of foliage in the center of the tree. It is equally evident that if infection of the outer leaves is to be prevented the first application of fungicides should be made to the spore-bearing terminal twigs before the blossoms and new leaves have appeared. By this last method the spring infection of the leaves will be in the main prevented and the fungicide on the terminal twigs will destroy the germinating spores that have been formed there.

As it was not known in time that infection of the spring foliage was from the terminal twigs, the first application of sprays was not made until April 15, after the leaves were well formed. Hence some of the end leaves were infested before the fungicides were applied. In consequence of this a small proportion of these end leaves fell off, but most of the foliage on the end shoots was retained, and nearly all of it over the major part of the tree. In applying the fungicides it was planned to have 2 treated trees alternating with 2 untreated ones. This gave control trees equal in number to those treated, while treated and untreated trees were equally representative of the whole.

Two fungicides were used:

(1) Ammoniacal solution of copper carbonate. The treated trees in the west half of the line received this spray.

(2) Modified eau celeste. This was used for treatment of the trees in the east half of the line. These were mostly larger than those at the west.

These two fungicides were made as follows:

Ammoniacal copper carbonate.†—In a wooden pail 5 ounces of copper

Ibid., Vol. VII, No. 2, p. 69.

†When copper carbonate can not be had of dealers it may be made at home, and usually at less than the market cost. For directions for making see Journal of Mycology, Vol. VII, No. 2, pp. 77–78. Also Farmers' Bulletin No. 7, p. 12. The latter may be had from the Secretary of Agriculture.

carbonate was dissolved in 3 pints of concentrated ammonia (26°). This solution was diluted with 45 gallons of water.

*Modified eau celeste (new formula).**—In 10 to 12 gallons of water 4 pounds of copper sulphate (crystals) were dissolved. To this solution was added 3 pints of concentrated ammonia (26°), and after stirring, this was diluted with water to 40 gallons. To this was added 6 to 8 gallons of water in which had previously been dissolved 5 pounds of sal-soda.

A cart sprayer holding about 50 gallons was used in these experiments, but for general field work a wagon tank similar to tanks in general use through southern California for the treatment of orange diseases, may be used. The pump should be of brass and kept well oiled, as the action of one of these sprays on metal is marked. The two lengths of spray hose should be about 24 feet long. To the free end of the hose was attached a piece of brass pipe 6 to 8 feet long and $\frac{5}{8}$ of an inch in diameter. This pipe is light, not easily affected by the fungicides as is the iron tubing, and is fitted with a stopcock so that the flow may be checked at any moment. To the end of the tube is fitted the Nixon nozzle. When applying the ammoniacal copper carbonate the No. 3 nozzle of this make works well; but it has been found that the brass netting used will not withstand the modified eau celeste. It is eaten through in a few moments and a suitable spray is no longer formed. The manufacturers have given assurance that they will have nozzles fitted with aluminium wire cloth the coming season, and this will probably withstand all mixtures suitable for fungicides.

It is very important that the mixtures be applied as a fine spray. When too coarse, the spray will collect in quantity on the leaves, and as a result they are burned. Further, there is a great loss of the fungicide when too coarse sprays are applied. Calm weather should always be selected for the treatment. In windy weather the trees will require nearly twice as much of the fungicide to properly reach all parts, and the work will not be done with the desired uniformity. With two length of hose 4 trees may be treated at each stand of the spray tank—2 on each side. All parts of the tree should be very thoroughly treated, both surfaces of the leaves as well as all of the branches. The light brass tube used is of great assistance in reaching the interior of the tree as well as the uppermost branches.

PLAN OF TREATMENT AND RECOMMENDATIONS.

The trees included in these experiments were numbered from west to east. Trees numbered 1, 2, 5, 6, 9, 10, 13, 14, 17, 18, and 19 were sprayed on April 15 with the ammoniacal solution of copper carbonate. Trees numbered 3, 4, 7, 8, 11, 12, 15, 16, 20, and 21 were left untreated.

* Differs from the ordinary modified eau celeste in the fact that ammonia is added before the sal soda.

The treated trees required about 2½ gallons of the fungicide at the time of the first treatment, as they were then in full leaf. When work was begun there was considerable wind blowing. Had it not been for this, 2 gallons of spray would have done equally good work. The time required to spray was eight to ten minutes for each tree. In calm weather five to eight minutes would be sufficient for a tree in full leaf, and four minutes for a tree not yet in leaf. The treated trees were carefully observed and it was not thought necessary to spray a second time until May 12. They were then treated with the same fungicide. This was the last treatment made, as the foliage retained the copper salts remarkably well and no heavy rains occurred later.

Trees numbered 22, 23, 26, 27, 30, 31, and 33 were first treated with the modified eau celeste on April 15. Trees numbered 24, 25, 28, 29, 32, and 34 were left untreated. The tops of the trees treated with this fungicide were, on the average, much larger than those treated with the ammoniacal copper carbonate. From 2½ to 3 gallons of fungicide would be required for such trees if the work be conducted in still weather and the spray be fine. In the present experiment there was considerable wind blowing, and the nozzles were imperfect because of the action of the sprays on the tip. Hence more fungicide was used than would otherwise have been required. About eight minutes were consumed in spraying each tree thoroughly.

After the first treatment there came a heavy rain. Nearly or quite 2 inches of water fell. Shortly afterward the trees were examined carefully, and it was found that the leaves were still well covered with the copper salts. A second thorough spraying was made with the same fungicide on May 12. From that time on the weather was dry, and the foliage and limbs of the treated trees retained the copper so perfectly that no other sprayings were necessary. As late as August 3 the mixture showed distinctly on all parts of the treated trees. It thus appears that modified eau celeste is an admirable spray to adhere, and in this dry climate, after the close of the winter rains, fewer treatments of plants are needed than in the East, where summer rains occur.

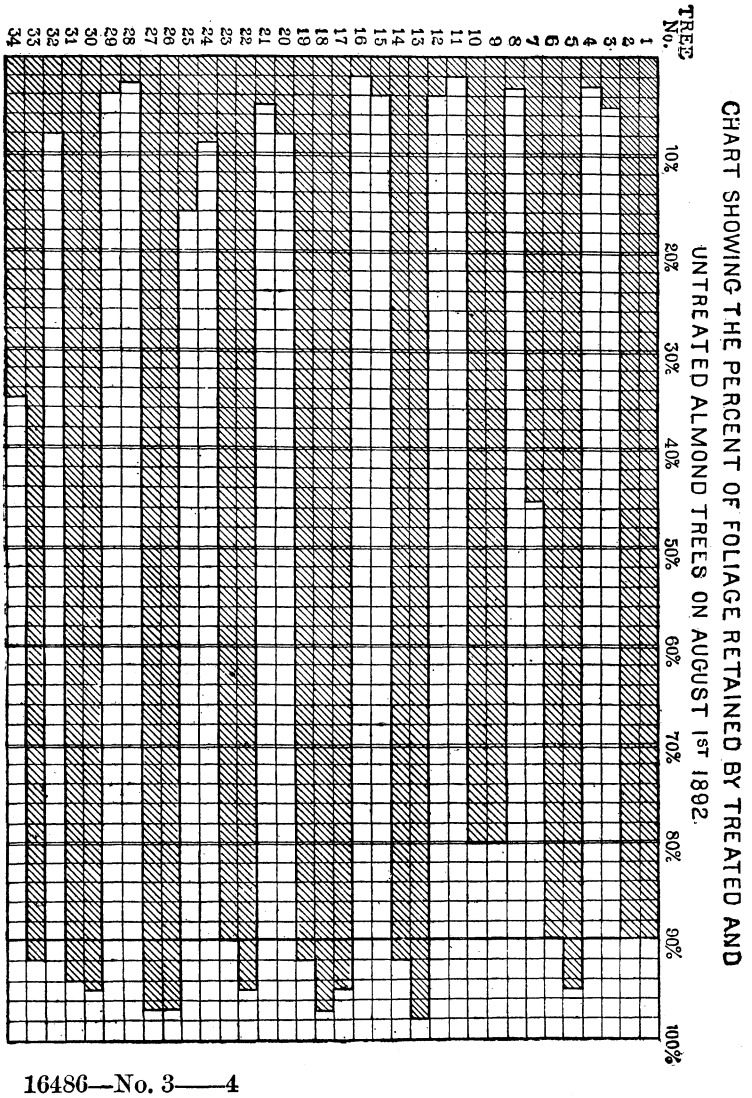
By June 14, the action of both the preceding sprays was evident. The leaves on untreated trees were becoming badly infested. The leaves on the outer twigs of the treated trees were also somewhat affected, but this was where infection had taken place from the branch previous to the first spraying. The main mass of foliage on nearly all treated trees was in excellent condition. On July 14 the results of the treatment were still more evident. The treated trees retained most of their foliage, while the untreated ones were rapidly becoming bare. Treated and untreated trees could be distinguished from a great distance. By August 1 the untreated trees were nearly bare, while the treated ones were yet in full leaf, with the exception of a few terminal twigs.

On August 3 an examination of the entire 34 trees was made and the percentage of the foliage remaining on all the trees was carefully estimated. The following table gives the results of this examination:

TABLE 1.—*Showing condition on August 3 of treated and untreated almond trees, sprayed with ammoniacal copper carbonate solution.*

No.	Treatment.	Per cent of foliage.	No.	Treatment.	Per cent of foliage.
1	Treated	90	12	Untreated	4
2	do	90	13	Treated	98
3	Untreated	5	14	do	92
4	do	3	15	Untreated	4
5	Treated	95	16	do	2
6	do	90	17	Treated	95
7	Untreated	45	18	do	97
8	do	3	19	do	92
9	Treated	80	20	Untreated	8
10	do	80	21	do	5
11	Untreated	2			

The results are shown in a graphic form in the accompanying figure:



Here are shown the satisfactory results arising from the use of the ammoniacal solution of copper carbonate. The 11 sprayed trees retained from 80 to 98 per cent of the foliage, the average being 91 per cent. On the other hand, the 10 untreated trees, with one exception, had not retained more than 8 per cent of the foliage. The one exception, apparently a tree not badly infested by *Cercospora*, had still upon it about 45 per cent of its foliage. The foliage remaining on the 10 control trees averaged 8 per cent, but exclusive of the one exceptional tree it averaged only 4 per cent.

TABLE 2.—*Showing condition on August 3 of treated and untreated almond trees, sprayed with modified eau celeste, new formula.*

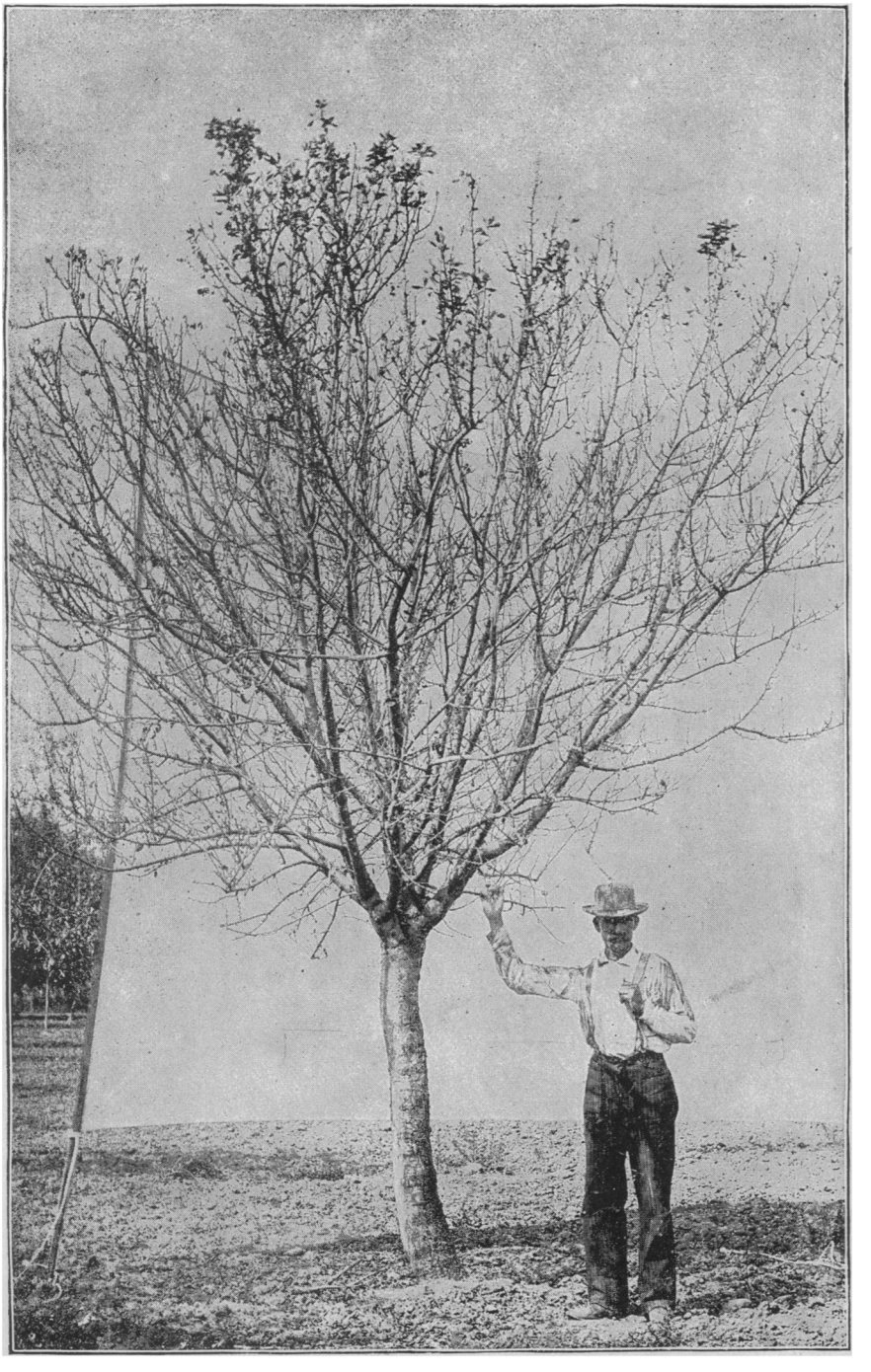
No.	Treatment.	Per cent of foliage.	No.	Treatment.	Per cent of foliage.
22	Treated	95	29	Untreated	4
23	do	95	30	Treated	95
24	Untreated	8	31	do	94
25	do	14	32	Untreated	8
26	Treated	97	33	Treated	92
27	do	97	34	Untreated	35
28	Untreated	3			

This table shows as good results from treatment with modified eau celeste as resulted from the use of ammoniacal copper carbonate. The 7 treated trees retained from 90 to 97 per cent of the foliage, the average being 94 per cent. The 6 untreated trees, with one exception, as in the former case, retained only from 3 to 14 per cent of their leaves. The exceptional tree in this case retained about 35 per cent of its foliage. Including this 1 tree, the average foliage on the untreated trees was 12 per cent, but exclusive of this tree it dropped to 7 per cent.

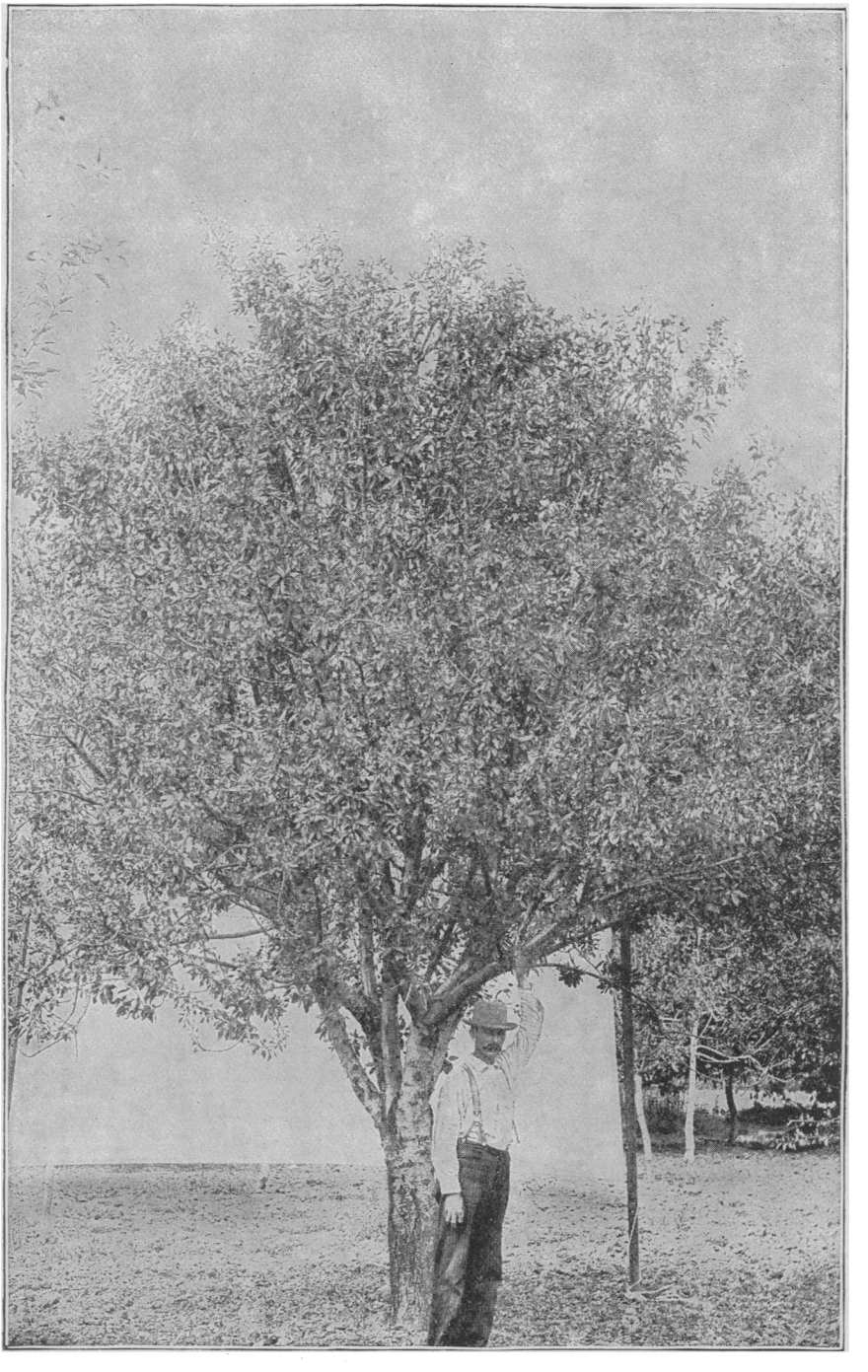
By comparing the trees treated with fungicides, we see that 91 per cent of foliage was preserved by the use of ammoniacal solution of copper carbonate, while 94 per cent was retained by using the modified eau celeste. This is so trifling a variation that it may be accounted for by the fact that the trees at the east, which were sprayed with eau celeste, are on better ground, are larger, and more healthy than those at the west, which were sprayed with the ammoniacal copper carbonate. These more favorable conditions show as well on the untreated trees as on the treated ones. The average amount of foliage retained on the untreated trees at the east was 3 per cent greater than that of the untreated trees at the west. This, curiously enough, is the difference in per cent of foliage on the treated trees at the east and on those at the west, which would seem to indicate that the action of the two sprays is almost exactly the same. If there exist any advantage of one spray over the other, so far as effectiveness as a fungicide is concerned, the advantages have not manifested themselves thus far.

Had the first treatment of these trees been made in the winter, as recommended below, the terminal leaves would not have become so generally infested by *Cercospora* and a higher percentage of foliage would have been retained. The method to follow is therefore evident.

ALMOND TREE. TREATED WITH AMMONIACAL COPPER CARBONATE. (PIERCE.)



ALMOND TREE. UNTREATED. (PIERCE.)



ALMOND TREE. TREATED WITH MODIFIED EAU CELESTE. (PIERCE.)

The first treatment should be given the naked trees, before they bloom. This treatment may be either with the modified eau celeste or the ammoniacal copper carbonate. Probably the last is preferable, as its presence is more easily detected, and it is well to be able to see if a sufficient deposit remains on the tree to prevent germination of spores at all times. This is especially necessary during the rainy season. The strength of this spray should be the same as that used in these experiments.

A second and third spray should be given the trees after they are in full leaf. The second shortly after the leaves are well developed and the third about a month later or after the spring rains have ceased. In making these sprays there may be added 10 to 15 per cent more water than was used in the experiments. Observations made on the treated trees lead to the conclusion that this reduction in strength would not detract to a serious extent from the fungicidal qualities of the sprays. It should always be borne in mind, however, that the treatment must be thorough to be effective. In case rains remove the copper salts after the third treatment another spraying should follow.

The cost of treating trees will vary greatly, according to the prices paid for chemicals and labor. Where large quantities of chemicals are purchased the prices should range about as follows:

	Per pound.
Ammonia (26°)	$0.08
Sal soda	0.02
Copper sulphate, crystals	0.06
Copper carbonate	0.40

At the above prices the ammoniacal copper carbonate required for treating a medium-sized tree three times, in all 6 to 7 gallons, will be close to 5 or 6 cents. The same amounts of the modified eau celeste will cost, at these prices, from 7 to 9 cents. As before stated, when the carbonate of copper can be made at home the cost is reduced, sometimes as low as 18 to 20 cents per pound. With proper facilities, the time required to spray a large almond tree in full leaf, in calm weather, should not exceed eight minutes, and four minutes should do the work on naked trees. This would give twenty minutes for three treatments in the season. Even this is probably allowing more time than would be given in general work.

DESCRIPTION OF PLATES.

PLATE XVIII. Tree No. 18 treated with ammoniacal copper carbonate solution. Amount of foliage retained estimated at 97 per cent. From photograph taken August 3, 1892.

PLATE XIX. Tree No. 16 untreated. Estimated to have retained only 2 per cent of its foliage. From a photograph taken August 3, 1892.

PLATE XX. Tree No. 27 treated with modified eau celeste. Calculated to have retained 97 per cent of its foliage. From a photograph taken August 3, 1892.